09/980147
JC03 Rec'd PCT/PTO 28 NOV 2001

2/PRTS

[10191/2043]

# METHOD AND DEVICE FOR TRIGGERING A REQUEST FOR TAKING CONTROL IN ACC-CONTROLLED VEHICLES

## Background Information

The present invention starts from a method as well as a device according to the definition of the species of the two independent claims for triggering a request for taking control (RTC) in vehicles having adaptive cruise control.

Methods and devices for regulating speed and/or acceleration have been known for a long time under the term "tempomat". Supplementing such a device with a sensor, which can recognize preceding vehicles and possibly obstacles located in the direction of travel, is also known. The device can thereby include in the control of vehicle speed, not only its own, i.e. internal traffic variables, but also traffic variables in the surroundings. Such devices are denoted as adaptive or dynamic vehicle speed controllers, in English as adaptive cruise control (ACC). Such an adaptive travel regulating system is intended to be a convenient assistance to the driver, and therefore the acceleration and deceleration dynamics, with which the control system activates the forward propulsion and the brakes of the vehicle, are limited. Furthermore, an adaptive vehicle speed regulator neither should nor can relieve the driver of any responsibility, but rather relieve him only of monotonous and tiring activities. Therefore, existing ACC systems are deliberately not made capable of independently initiating sharp braking nor indeed full braking, although the sensory system is able to recognize dangerous situations. In dangerous situations, all existing ACC systems provide a so-called request for taking control, which is activated when the maximum deceleration provided by

the automatic system is no longer sufficient to avoid a collision. The request for taking control signals the driver acoustically, optically, haptically or kinesthetically that manual intervention using the brake pedal is becoming necessary, since the system in its given design will no longer be able to master the situation before long. In supplementary fashion, the driver has priority over the vehicle control system at any time, in that he can operate the gas or brake pedal and override or deactivate the system, and thereby put the automatic drive control out of commission.

A fundamental description of such a device was contained, for example, in the paper "Adaptive Cruise Control - System Aspects and Development Trends," given by Winner, Witte et al., at SAE 96, February 26 to 29, 1996 in Detroit (SAE Paper No. 961010). Here the dynamic restriction of the system for the purpose of riding comfort was described in detail.

The request for taking control was mentioned in this article as possibly being an acoustic signal which is activated when no sufficient deceleration can be made available so as to react fittingly to the instantaneous situation.

One method and device for travel regulation are known from DE 195 44 923 A1. Among other things, this system has a radar system and a vehicle speed sensor, from whose measured values an acceleration requirement signal is formed, which is used to activate the throttle and the brakes (EGAS system). A limiter assures that the acceleration requirement signal does not exceed the range between a predefined maximum or minimum value, in order to guarantee a designated travel comfort to the vehicle passengers. In this system, the driver is notified using a blinking light, a tone generator, a haptic device or a combination of these possibilities. These signal elements are activated when the current deceleration requirement of the vehicle exceeds or approximately reaches the maximum

permissible deceleration for the vehicle, and the vehicle is subject to travel control at the same time.

In EP 0 348 691 B1, concepts for haptic signaling are pointed out, however, no method is described which points to a reference to triggering a request for taking control.

Description of the Present Invention, Object, Solution and Advantages

It is accordingly the object of the present invention to develop criteria with the aid of which the activation of a request for taking control can be triggered, so that the frequency of false alarms can be reduced to a possible minimum.

This object is achieved by the features of the main claims.

According to the present invention, this happens by at least two criteria with respect to deceleration values having to be simultaneously fulfilled for activating the request for taking control. In the later exemplary embodiment, these are two inequalities with regard to the deceleration values aSoll and aWarn, which have to be fulfilled simultaneously. In this connection, the two deceleration-related variables are of such a nature that they lead to as complete as possible a reduction in false alarms. Furthermore, the decision thresholds "aMaxDecel + Offset1" 221 as well as "aMaxDecel + Offset2" 231 of these criteria are not given, as they were up to the present, by constant threshold values, but they are changed dynamically, as a function of instantaneous values, such as vehicle speed.

Corresponding to the situation in known systems, for the activation of the actuators, for the setting of the throttle and for brake operation, only the size of the acceleration requirement is used: in the present case this is denoted as aWarn. If this variable aWarn undershoots the negative

acceleration value which corresponds to the brake energizing hysteresis, the vehicle is decelerated, the braking force depending on the absolute value of aWarn. Now, if short term error measurements appear, the system will perhaps trigger a request for taking control, even though the situation would not require it. In this manner, false alarms are created, which can irritate the driver and make the system appear unsophisticated. For the solution of this problem a second acceleration value is introduced, which is subsequently denoted as aSoll. This value aSoll, just as aWarn, must undershoot a certain negative acceleration threshold, denoted as "aMaxDecel + Offset2" 231 in the exemplary embodiment, so that both criteria together trigger the request for taking control. In this connection, aSoll is the value which is passed on to the brake control, or, in the case of propulsion, is passed on to the engine control, and is there recalculated as the desired engine torque. In order to impart comfort to the vehicle passengers, the value aSoll, which acts directly on the power train and the deceleration elements, is restricted in several ways. Thus, the maximum admissible acceleration value is limited by a positive and also by a negative limiting value, so as to impart a comfortable riding sensation. Furthermore, the change over time of the acceleration value is bounded in the limiter 103, in order to prevent thereby the so-called "jolt" in response to a load alteration. The two switching thresholds "aMaxDecel + Offset1" 221 and "aMaxDecel + Offset2" 231 for the input values aWarn and aSoll, in response to whose undershooting the request for taking control 109 is triggered, can be changed during the operation, according to the present invention, so that the switching threshold values can be set to the instantaneous driving situation. In this connection, the value aMaxDecel is formed as a function of the instantaneous driving speed, whereby, at different speeds, one can also select the starting point of the deceleration differently.

These innovations avoid false alarms of the ACC request for taking control. If the system recognizes an object in the travel-path area of the vehicle even for a very short duration, for example, through disturbances in the side lane or error measurements, by using the measures of the present invention, the request for taking control is no longer triggered immediately, but braking is begun. If this object disappears again before the instantaneous deceleration aSoll corresponds to about the maximum deceleration "aMaxDecel + Offset2" 231 available to the system, braking is discontinued again without jolting, and the vehicle continues under normal operation. However, if the detected object does not disappear, and the instantaneous deceleration approaches the maximum deceleration "aMaxDecel + Offset2" available to the system, or reaches it, the request for taking control 109 is triggered if the system still predicts that it can no longer decelerate the vehicle in time or in sufficient measure. Experience has also shown that braking action, as a rule, turns out very differently in the case of high speeds and in the case of low speeds. That is why the present invention also made the automatic braking action of the ACC system a function of the instantaneous speed, in order thus to generate a braking action which corresponds to that of a responsible driver. This further yields the impression of comfortable and pleasant travel, also in view of the time gradient limitation of the value aSoll.

Description of the Drawings and the Exemplary Embodiment

In the following, an exemplary embodiment of the present invention, as well as a possible functional sequence scenario, which can occur during ACC operation, are explained with the aid of two drawings.

Figure 1 shows a block diagram of an exemplary embodiment according to the present invention.

Figure 2 shows a possible functional sequence scenario which can occur during operation of the vehicle under ACC, made up of four partial diagrams in each of which one variable of the ACC system is plotted against time.

Figure 1 shows an ACC system in a block diagram, in extract. What is shown in detail is how the decision to trigger the request for taking control is formed. The distance dZO between one's own and the preceding vehicle, the relative speed of the target object vRelZO in relation to the preceding vehicle, as well as the acceleration of the target object aZO enter as input variables into function block 101, in which the value aWarn is formed. This formation of the value aWarn can be accomplished by calculation by means of a mathematical formula or by storing a characteristics map or a table in block 101. In the case of doing the calculation by mathematical formula, aWarn is advantageously calculated from

$$aWarn = ((sign(vRelZO)(vRelZO)^2)/(2dWarn))+aZO \qquad (1)$$

where, in turn, the warning distance dWarn (the relative deceleration path) is calculated from

$$dWarn = (fWarn\ dZO) - Offset3 \qquad (2)$$

fWarn is a factor here, which can either be definitely predefined as a parameter or variably calculated; in the case it can preferably be a function of the set time gap. Using this factor fWarn, for example, the time gap set by the driver or a travel program (comfortable, safe, economical, sporty,...) predefined by the driver can be taken into consideration.

The value of aWarn thus calculated is then passed on to function block 105.

In function block 102, in a manner similar to the one in block 101, using the input variables distance dZ0, the relative speed of the target object vRelZO as well as the acceleration of the target object aZO, the value aSoll is formed. This is done again, as in block 101 by using a mathematical formula or by storing characteristics maps or tables. The value aSoll thus formed is routed to a limiter which limits this value with respect to minimum or maximum values as well as with respect to the time-related acceleration change, and routes it to decision block 106 as the value aSetpointStar. At the same time, this value aSetpointStar is passed on to the throttle control and the brake control, which are marked in Figure 1 as "EGAS System", where they are converted to propulsion and braking systems. In function block 104 the maximum deceleration controllable by the ACC system, aMaxDecel, is formed, and forwarded to decision blocks 105 and 106. The maximum deceleration controllable by the adaptive driving speed regulating system, "aMaxDecel + Offset2" is changed there as a function of the instantaneous driving speed, so that the system provides at all times a dynamics region that is as great as possible but nevertheless comfortable.

In block 105 an inequality is monitored. It is examined here whether the condition

$$\text{aWarn} < \text{aMaxDecel} + \text{Offset1} \qquad (3)$$

is fulfilled. If this is the case, a signal is sent in the appropriate manner to subsequently connected AND element 107 that the condition that was to be examined in block 105 is fulfilled. In the same way, decision block 106 examines whether the condition

$$\text{aSetpointStar} < \text{aMaxDecel} + \text{Offset2} \qquad (4)$$

is fulfilled, whose variables are composed of the input values aSetpointStar and aMaxDecel. In case inequality (4) is

fulfilled, decision block 106 signals, also in suitable fashion, to AND element 107 that the trigger condition is fulfilled.

The offset values Offset1 and Offset2 are parameters whereby the warning thresholds according to equation (3) and equation (4) can be further varied and optimized.

The AND element 107 monitors whether all inputs report simultaneously that the conditions of preconnected decision blocks 105 and 106 are fulfilled.

If this is the case, then AND element 107 signals the OR element 108 that the conditions for triggering the request for taking control are fulfilled. The OR element 108 signals to request for taking control 109 that the latter is to be triggered, and that the driver is thereby notified that the comfortable braking of the system is not sufficient for obtaining enough deceleration.

By the use of function block 110, which is connected to one of the inputs of AND element 107, as well as of 111, which is connected to an input of OR element 108, additional criteria with regard to activating the request for taking control can be taken into consideration.

Thus, the output of function block 110 is connected to the input of AND element 107. This function 110 can expediently be monitoring the active operational state. In this case, block 110 would monitor the operational state of the ACC control and report this to block 107 in suitable fashion. It would also be expedient to install a function of speed as AND condition, which would permit activation of the request for taking control only when the vehicle fulfills certain speed requirements. This has the result that the taking-control signal is indeed activated only when the ACC control and regulating device can actively control the gas and the brakes.

In the same way, one can advantageously determine whether the ACC control and regulating device is functioning properly, by using a self-diagnosing function. In case this device does not work without error, an output signal is generated in function block 111 which OR element 108 receives, and finally causes the activation of the request for taking control. This guarantees that the driver is requested to take control in the case of operational failure and that the ACC control and regulating device can switch itself off safely, following the activation of the brake pedal. Furthermore, it is advantageous to check whether the sensor function is enssured. Thus, it is expedient to process a blindness recognition signal or a rain recognition signal, or to process a signal which brings about a warning of standing objects in one's own lane, during limited vision conditions, such as in fog.

Figure 2 illustrates a scenario for a vehicle operated by an ACC, as can happen at any time in reality. This illustration is made up of 4 diagrams, drawn one below another, in which, in each case one characteristic variable is plotted against time. In diagram 210 the distance to the target object dZO is plotted against time. In diagram 220 the warning acceleration aWarn was also plotted against time. The drawn-in borderline 221 here denotes a threshold value "aMaxDecel + Offset1", and when it is exceeded, a corresponding signaling is passed on to AND element 107 in Figure 1.

In diagram 230 the restricted desired acceleration aSetpointStar was plotted against time. This is the variable which also has passed on to it a control for the electronically controlled throttle (EGAS) or an electronically controlled brake. The drawn-in value 231 here again represents the threshold value "aMaxDecel+Offset2", at the undershooting of which a corresponding signaling is also passed on to AND element 107. In the bottom diagram 240 the request for taking control is represented as a digital signal. Here the transition from "0" to "1" stands for activation of

the request for taking control signal. The pulse duration of the RTC(t) signal is a function of the duration of the taking-control signal. When the signaling is ended, the RTC(t) curve jumps back from "1" to "0".

The 4 diagrams 210, 220, 230 and 240 are arranged in such a way that the time lines run parallel. One can thereby represent places at the same point in time by vertical lines which are entered dotted in Figure 2. Special points in time are lettered as Latin letters a to f at the lower edge of Figure 2.

At point t=0 in dZO-t diagram 210, a certain distance dZO(t=0) prevails between the ACC-controlled vehicle and the preceding vehicle which is held constant.

At point in time t=a an additional object of reflection suddenly appears from nowhere, which is at a very short distance from the ACC-controlled vehicle, is detected for only a very short time, and disappears again just as suddenly. In this case, the system tries to make available a strong deceleration which is far below warning threshold 221 of the aWarn-t diagram 220. Because of that, block 105 in Figure 1 passes a corresponding signal on to AND element 107. Signal aSetpointStar, which also controls the propulsion and brake elements, is created essentially in the same way as aWarn, the only difference being that aSetpointStar is limited as to maximum value as well as gradient. Thus jumps, steep transitions as well as values great in amount are excluded as far as aSetpointStar is concerned. Until the desired end values for aSetpointStar are adjusted, a certain time lapses, which is why this signal can be denoted as being inert or delaying compared to aWarn. In the aSetpointStar-t diagram 230 the gradient for the curve tangents, is sketched in each case as a gradient triangle. Thus the gradient of gradient triangles 232 is equal in amount to the maximum possible gradient, since in the exemplary case at time t=a the maximum

deceleration controllable by the ACC, or even more is required. The deceleration requirement at point a lasts only a very short time, so that the curve in aSetpointStar-t diagram 230 does not reach triggering threshold 231. Thus, no triggering signal is given by block 106 to AND element 107 either, which is why activating the request for taking control does not occur, and the RTC-t curve in 240 remains at "0".

Between the two points b and c, the preceding vehicle applies its brakes gently. It follows that point b is the starting point in time of this gentle brake maneuver and that c is the end point in time of this brake maneuver. The distance dZO in diagram 210 decreases during this time, until the brake maneuver is closed at point in time t=c. The deceleration values aWarn in diagram 220 are so small in amount between t=b to t=c that triggering threshold 221 is not reached, which means logically that braking is so slight that the brake dynamics region of the ACC system is sufficient for a corresponding deceleration. In the aSetpointStar-t diagram 230 this becomes noticeable in that the curve takes a flatter course and the tangent having gradient triangle 233 is also flatter than in the situation at point t=a. Since the ACC system was able to make available sufficient deceleration in the case t=b to t=c, in the case of this gentle braking a request for taking control is also not activated, and so the curve in the RTC-t diagram 240 still remains at "0".

In the following, the preceding vehicle accelerates again, which becomes noticeable by the increase in distance dZO and the decrease of the deceleration.

At point t=d the preceding vehicle decelerates again, but not very strongly this time. The value of aWarn immediately darts downwards and crosses the triggering threshold 221 of aWarn. The value of aSetpointStar drops off at the maximum steepness 232 possible, and reaches triggering threshold "aMaxDecel + Offset2" 231 at point t=e.

As of this point t=e, both triggering criteria are simultaneously fulfilled, and triggering the request for taking control takes place as described in Figure 1, by the AND element 107 and the OR element 108. This is illustrated in the RTC-t diagram 240 by the curve jumping from "0" to "1" at point t=e. At this point in time e the driver is informed that the deceleration of the ACC system is not sufficient to prevent a collision.

At point t=f the driver decides to step on the brake pedal in order to achieve a greater deceleration than could be made available by the ACC system. As the driver intervenes by braking at point t=f, the ACC system is simultaneously deactivated.

Triggering thresholds 221 and 231, as was mentioned before, are not fixed, but rather variable thresholds, and can be made functions of parameters such as speed. Curves "aWarn(t)" 220 and aSoll(t)" 230 are normalized in each case on thresholds 221 and 231, for the purpose of making it more understandable, so that the thresholds themselves appear as a constant value, that is, as horizontals in the diagram.

The calculation of aWarn takes into consideration not only the necessity of reducing the present relative speed within the distance available dWarn, but also the absolute deceleration of the target object which has to be additionally produced to avoid a collision. The value dWarn can further be modified by a factor fWarn, to take into account the time gap or a driving program predefined by the driver.

If the request for taking control is triggered as at point t=e, it can either alarm the driver for a fixed, definite time period, or it can alarm the driver until the triggering criteria are no longer fulfilled. Of necessity, the request has to be activated for a minimum time, since even during a very short period of alarm, this must be noticeable to the

driver and clearly understandable. It is also expedient to have a minimum time period elapse between two requests for taking control, so as not to overload the driver with ACC alarms.

However, besides changing the request for taking control by such time conditions, one can also do it as a function of distance conditions. Thus, it is expedient, for example, that a request for taking control that is once activated has to remain so until a minimum distance from the target object has been achieved again, or the distance from the target object is getting larger again.

In the RTC-t diagram in Figure 2, the deactivation of the request for taking control in the form of a negative transition from "1" to "0" is not shown, since this would have a different profile depending on time duration and resetting conditions.

By the use of the measures described in one of the mentioned types of embodiment, it is possible drastically to reduce the probability of a false activation of the ACC request for taking control. The motor vehicle driver can thereby have more trust in the request for taking control than up to now, and in that case the request for taking control will be received more meaningfully at the same time.